Fish Abundance in the Rivers of Thong Pha Phum

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Abstracts: Fishes captured in Thong Pha Phum between 2001 and 2004 during the course of another investigation are herein collated by species, their numbers·100m^{-2} of river surface area and environmental conditions at the time of their capture. Some casual associations are offered between the abundance of some species and their environment, in particular, elevation, river size and ionic strength of the water.

Introduction

The information in this report was gathered in the course of an ecological research project conducted between 2001 and 2004 and is not intended as a comprehensive study of the species present in Thong Pha Phum. It is offered in the hope that it may be a useful source of information, perhaps as a starting point for another study. Fish were captured by electrofishing at sites on rivers, small and, by comparison, large as well as tributaries of the larger rivers and population size estimated by the depletion method. Included are some measurements of the environmental conditions at sites when fish were captured. Statistical limits are available for all population estimates but are not included in this report for the sake of brevity.

Materials and Methods

A total of 83 sites were sampled on eight small and three comparatively large rivers. The eight smaller rivers were Lichia, Kopak, Krengkavia, Thi Khrong, Satamid, Kroeng Tako, Kratenjeng and one whose name was not found. The larger rivers were Ban Rai, Khayeng and Phacham Rai. The fishes and limnological characteristics are described separately for each of the smaller rivers and, for the two larger rivers, Khayeng and Phacham Mai, separately for the tributaries and main channel. Names were not obtained for all tributaries and one small rive (Fig. 1). The tributaries for Phacham Mai included Pilok, E-pu, Pak Kok and three for which names were not found. On Khayeng River, 13 unnamed tributaries were sampled Figs. 2 and 3). No tributaries of Ban Rai River were sampled. Some tributaries and main channels were sampled at a number of sites and some

Figure 1. Waterfalls in the headwaters of (A) Pilok and (B) Pak Kok rivers.

Figure 2. A sample site on a first order tributary of Khayeng River.

Figure 3. A sample site on the main channel of Khayeng River.

seasonally. Latitude and longitude of each site is available but not included in this report.

The decision on the length of stream to electro-fish was based, in part, on the available length of similar habitat as well as by physical constraints imposed by water velocity in concert with discharge (Fig. 4). Prior to electro-fishing, conductivity was measured and used to set the voltage and electrical wave configuration to maximize fish capture efficiency and minimize harm to fish. Then, seine nets of about 3mm mesh were installed across the upper and lower limits of the site and their groundlines weighted with large rocks to reduce the probability of emigration from or immigration into the sampling reach (Figs. 5 and 6). A station was electro-fished by moving systematically from one retaining net to the other, beginning downstream or upstream based on visibility, water depth, velocity and turbidity. Electro-fishing involved two people, one to operate the shocker and one to capture and remove the temporarily stunned fish (Figs. 7 and 8). Usually four or five passes were made at a site. After each pass, fish were anaesthetized in a dilute solution of methaine tricaine sulfonate (approximately 150 $mg \cdot l^{-1}$), then identified and enumerated. After fish recovered from the anesthetic, they were released upstream or downstream from the retaining nets. When unable to assign species status in the field a small sample of the unidentified species was killed by an overdose of anesthetic and preserved in 10% formalin for subsequent identification in the laboratory. Current systematics of Thai freshwater fishes is equivocal. For this report the classification system of Nelson (1994) was followed along

Figure 4. Walking a river in search of a suitable site.

Figure 5. Blocking one end of a site on a first order tributary with a seine net.

Figure 6. Blocking one end of a site on a third order river with a seine net.

Figure 7. Sampling fish at a site with a backpack

Figure 8. A small fish catch.

with most of the names given in the check list of Vidthayanon et al. (1997). Names for a few species were updated from recent taxonomic revisions. Fish were identified from a number of sources including: Smith (1945), Brittan (1954), Banarescu (1971), Roberts (1982, 1989, 1994), Kottelat (1984, 1988, 1989, 1990, 1998, 2004), Lumlertdacha (1986), Karnasuta (1993), Rainboth (1996), Fang and Kottelat (1999), Ng and Kottelat (2000), Freyhof and Serov (2001), Nalbant (2002), Tan and Ng (2005) and many others. A voucher collection was prepared and is maintained in the Institute of Marine Sciences at Burapha University, Bangsaen, Chonburi (Catalogue number –BIMS: FF. 0001- 002). Fish were preserved in 10% formalin for 10 days and then transferred to 70% ethanol for permanent storage.

Physical and Chemical Variables

On each sampling occasion, width (± 0.1 m), depth (± 1 cm), and velocity (± 1 cm s^{-1}) of the stream reach were measured, each at least three times, and the means used to estimate discharge ($l \cdot s^{-1}$). Depth was the average of 3-5 measurements made at approximately equal intervals across the river. Velocity was measured at the surface and adjusted to represent the vertical mean flow rate (Gillner and Malmqvist, 1998) at each of three equally spaced locations across a station's width. Regularly calibrated meters were used to measure temperature (±0.1°C), conductivity (±5 $\mu S \cdot cm^{-1}$), turbidity (NTU), pH (± 0.1) and dissolved oxygen (± 0.1 $mg \cdot l^{-1}$). In addition, a water sample was collected for measures of ammonia ($mg \cdot l^{-1}$), total iron ($mg \cdot l^{-1}$), alkalinity ($mg \cdot l^{-1}$, pH 4.5), silica ($mg\ l^{-1}$) and true color ($mg \cdot l^{-1}$ platinum- cobalt color units, CU), (APHA, 1992). Elevation was measured by GPS.

Substrate at each station was collected with a hand-held acrylic corer (5 cm inner diameter) to a depth of 10±3 cm. Particles on the surface larger than the diameter of the corer were removed before a sample was taken and included. Samples were air dried and sieved to determine particle size distribution by weight. Six size categories were adopted from the Wentworth scale (Giller and Malmqvist, 1998), > 150 mm (boulder to large cobble), 150-60.1 mm (large cobble to large pebble), 60-5.1 mm (large pebble to coarse gravel), 5- 3.1 mm (medium to fine gravel), 3-0.51 mm (fine gravel to coarse sand), <0.5 mm (medium sand to silt) and the mean particle size calculated. The substrate for each station was coded into six categories based on mean particle size with 1 being the smallest and 6, the largest. The substrate at a few stations was solid or almost solid bedrock and coded as 7. An average of three replicate substrate samples (range of 2-6) was collected at 40 stations. Variation was similar within each particle size category with an overall mean (±SD) of 26±12 %. One sample was collected at all other stations.

Total abundance of fish within a station was calculated by the maximum likelihood technique along with the capture efficiency for each pass (Carle and Strub, 1978). Numbers for many species were small and not amenable to this technique. Hence a conversion factor consisting of the total abundance estimate divided by total number of fish caught was applied to adjust the numbers of each species captured. Fish abundance was arithmetically adjusted to an area of 100 m^2.

Results and Discussion

A total of 70 taxa were identified, 61 to species, eight to genus and one to family. Cyprinids dominated in numerical abundance and species richness (Tables 1 and 2) followed distantly by the Balitoridae (Tables 3 and 4) and Channidae (Tables 7 and 8) (Figs. 9 and 10) Average abundance of cyprinids, all species combined, in the small rivers was approximately 108 $fish \cdot 100m^{-2}$, slightly above that for the larger rivers at 84 $fish \cdot 100m^{-2}$. Balitoridae contributed approximately 12 and 32 $fish \cdot 100m^{-2}$ in the smaller and larger rivers, respectively (Tables 3 and 4). Average number of channids was 7 $fish \cdot 100m^{-2}$ in both river categories (Tables 7 and 8). Contributions from all other families were substantially lower. Species richness patterns mirrored those of abundance with cyprinids contributing 26 species, balitorids, 12 species and cobitids and bagrids each contributing five species (Tables 5 and 6). The number of species represented from each family was quite similar in large and small rivers, however, in the more species rich families some species found in either the larger or smaller rivers were absent in the other. For example, five cyprinids present in small rivers, *Paralaubuca riveroi, Poropuntius deauratus, Puntius brevis, Labeocheilus rhaboura* and *Osteochilus waandersii* were absent in the larger river samples. In the larger river samples eight cyprinids, *Opsarius koratensis, Opsarius*

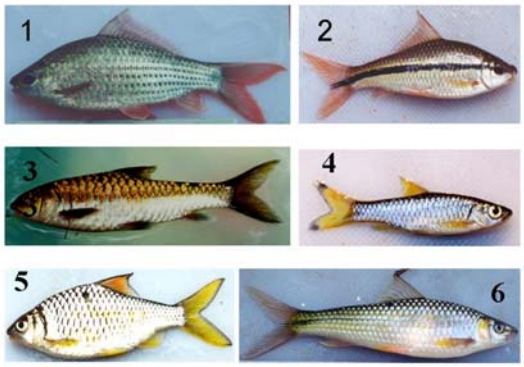

Figure 9. A selection of species from the family Cyprinidae; 1, *Osteocheilus hasselti*; 2, *Systomus lateristriga*; 3, *Neolissocheilus stracheyi*; 4, *Rasbora caudimaculata*; 5, *Mystacoleucus marginata*; 6, *Lobocheilus quadrilineatus*.

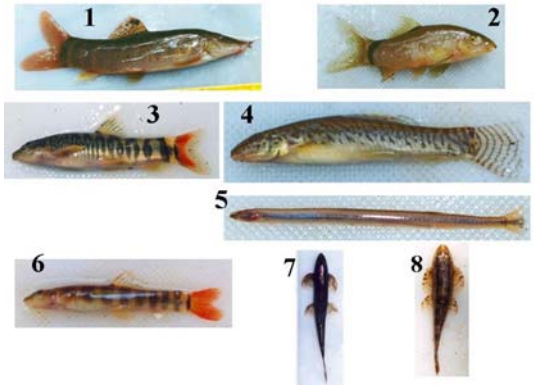

Figure 10. A selection of species from the family Balitoridae; 1, *Syncrossus beautforti*; 2, *Yasuhikotakia morleti*; 3, *Schistura mahnerti*; 4, *Acanthocobitis botia*; 5, *Pangio anguillaris*; 6, *Homaloptera smithi*; 7, *Balitora kwangsiensis*

pulchellus, *Rasbora borapetensis*, *Neolissochilus soroides*, *Cyclocheilichthys armatus*, *Barbodes gonionotus*, *Systomus orphoides* and *Systomus* sp. were present that were absent in the samples collected from the smaller river sites. This pattern was similar for other families although differences were not as great (Fig. 11).

Habitat requirements are directly or indirectly related to those for an individual's growth and survival or its niche. The importance of habitat has long been recognized through studies on environmental preferences (Fry, 1971) and influences on individual species and assemblages (Meffe and Sheldon, 1988). In Thong Pha Phum, fishes display different levels of apparent habitat preference. Thus some prominent species in the larger rivers were absent in the habitat provided by smaller rivers such as *Acanthocobitis zonalternans* and *Schistura desmotes*. In contrast other species apparently seek smaller habitats such as *Poropuntius deauratus* and *Puntius brevis*. Silurids tended to be more common in the larger rivers although they seldom were abundant in either habitat. For other species river size seemed of little importance (Fig. 12) *Channa gachua* was widespread and equally abundant in large and small rivers. Similarly, habitat size did not seem to influence abundance of *Mastacembelus armatus*, although their numbers were never large. Other important habitat characteristics included elevation, ambient ionic concentration and cover.

Species richness varied inversely with elevation at least above 400m. At the highest elevation, 853m, richness was reduced to a single species of Schistura, here termed species

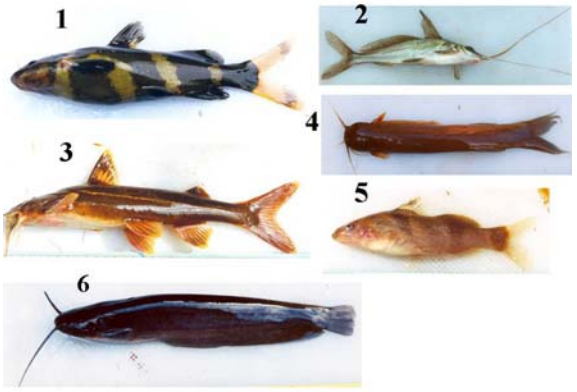

Figure 11. A selection of species from the order Siluriformes; 1, *Leiocassis siamensis*; 2, *Mystus singaringan*; 3, *Glyptothorax platypgonoides*; 4, *Amblyceps macronatum*; 5, *Mystus havmolleri;* 6, *Pterocryptis cochinensis*

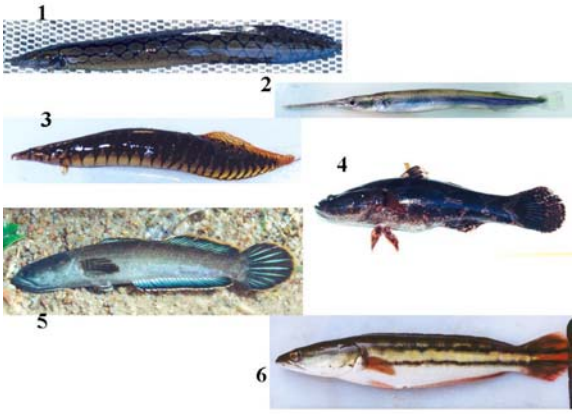

Figure 12. A selection of species; 1, *Xenenthodon cancilla*; 2, *Mastacembelus armatus*; 3, *Macrognathus circumcintus*; 4, *Oxyeleotris marmorata*; 5, *Channa gachua*; 6, *Channa micropeltes*

Table. 1 Fishes of the Family Cyprinidae from the smaller rivers in Thong Pha Phum. Numbers are average numbers of fish·100m^{-2}. N indicates the number of sites sampled.

	Lichia	Kapok	Kratenjeng	Unknown	Kroeng Tako	Satamid	Thi Khrong	Krengkravia
N	5	5	2	1	3	1	1	1
Paralaubuca riveroi	0.1	0	0	0	0	0	0	0
Opsarius koratensis	0	0	0	0	0	0	0	0
Opsarius pulchellus	0	0	0	0	0	0	0	0
Brachydanio albolineatus	0	0	0	0	17.9	0	12.7	0
Danio acrostomus	37.6	1.3	24.9	22.4	2.6	117.2	3.2	1.5
Rasbora borapetensis	0	0	0	0	0	0	0	0
Rasbora caudimaculata	0.3	8.8	0.5	3.1	46.3	0	133.6	0
Neolissochilus stracheyi	24.4	0	2.8	1	0	40.5	0	0
Neolissochilus soroides	0	0	0	0	0	0	0	0
Cyclocheilichthys apogon	0	1	2.7	0	0	0	0	0
Cyclocheilichthys armatus	0	0	0	0	0	0	0	0
Mystacoleucus marginatus	23.4	7.2	19.1	0	45.5	0	0	3
Barboides gonionotus	0	0	0	0	0	0	0	0
Poropuntius deauratus	0	0	0	3.1	0	0	0	0
Hampala macrolepidota	5.2	0.1	0.2	0	0	0	0	0.4
Puntius brevis	0	0.1	0	0	2.9	0	0	0
Systomus binotatus	0	3.5	0	0.5	33.1	0	23.9	0
Systomus lateristriga	0	0	0	0	0	0	0	0
Systomus orphoides	0	0	0	0	0	0	0	0
Systomus stolitezkae	0	0	0	0	0	0	9.5	0
Systomus sp.	0	0	0	0	0	0	0	0
Labeobarbus leptocheilus	0	0.1	0	0	14.5	0	0	0
Labocheilus rhaboura	0.1	0	0	0	0	0	0	0
Osteochilus hasselti	10.6	5.8	7.6	0	60.8	0	30.2	0
Osteochilus waandersii	7.7	0	0.5	0	0	0	0	0
Garra fuliginosa	10.8	0.6	7.4	0	0	2.1	0	0
Garra sp.	4.7	0	8	5.1	0	0	0	0.4

1 until its status can be decided.. As elevation declined to 700+m, species numbers increased to include two cyprinids, *D. acrostomus* and *S. binotatus*, two unidentified species of *Schistura*, *C. gaucha* and *M. albus*. Species richness seemed not to be impaired by elevation under approximately 400m. Some species were commonly found in water of high ambient ionic concentration including *O.hasselti, S. binotatus, M. marginatus and R. caudimaculata*. Not surprisingly a few other species seemed to prefer water of low ionic strength, notably *D. acrostomus, C. gachua, P. fasciatus* and *M. albus*. In small streams, species numbers correlated positively with cover.

In summary, fishes and their abundances are described for the smaller and larger rivers in Thong Pha Phum and, in a general way, related to habitat characteristics.

Acknowledgements

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Table 2. Fishes of the Family Cyprinidae from the larger rivers in Thong Pha Phum. Numbers are average numbers of fish·100m^{-2}. N indicates the number of sites sampled.

	Ban Rai	Khayeng		Pracham Mai	
		Tribs	Main	Tribs	Main
N	6	26	13	18	1
Paralaubuca riveroi	0	0	0	0	0
Opsarius koratensis	0.2	0.4	0.1	<0.1	0
Opsarius pulchellus	0	0	0	0	5.1
Brachydanio albolineatus	0	1.4	0	9	0
Danio acrostomus	0.2	44	0	64.6	1.4
Rasbora borapetensis	0	0	0.1	0	0
Rasbora caudimaculata	6.5	2.8	2.5	14.1	0
Neolissochilus stracheyi	0	0.2	0	8.9	11
Neolissochilus soroides	0	0	0	3.4	0
Cyclocheilichthys apogon	1	5.9	2	0.1	0
Cyclocheilichthys armatus	0	0.1	1.5	0	0
Mystacoleucus marginatus	15.5	5.8	59	19.5	0.1
Barboides gonionotus	0	0.1	0.1	0	0
Poropuntius deauratus	0	0	0	0	0
Hampala macrolepidota	0	0.2	1.7	<0.1	0
Puntius brevis	0	0	0	0	0
Systomus binotatus	4.6	6.6	2.4	30.7	0
Systomus lateristriga	0	0	0	0	0
Systomus orphoides	0.4	0.4	0.2	8.9	0
Systomus stolitezkae	1.7	0	0.3	2.9	0
Systomus sp.	0	0	0	<0.1	0
Labeobarbus leptocheilus	0.1	0	0	0	0
Labocheilus rhaboura	0	0	0	0	0
Osteochilus hasselti	2.8	3.9	41.6	9.7	0
Osteochilus waandersii	0	0	0	0	0
Garra fuliginosa	0	1.5	2.8	1.2	2
Garra sp.	0	0	1.1	9.5	0

Table 3. Fishes of the families Balitoridae and Cobitidae from the smaller rivers in Thong Pha Phum. Numbers are average numbers of fish·100m^{-2}. N indicates the number of sites sampled.

	Lichia	Kapok	Kratenjeng	Unknown	Kroeng Tako	Satamid	Thi Khrong	Krengkravia
N	5	5	2	1	3	1	1	1
Balitoridae								
Acanthocobitis botia	0	0.5	0	0	0	0	0	0
Acanthocobitis zonalternans	0.4	2	0.5	0	0	0	0	1.5
Balitora kwangsiensis	10.4	0	0.2	0	0	0	0	0
Homaloptera smithi	0.7	0.4	0.8	0	0	0	9.5	0.4
Noemacheilus masyae	1.8	2.1	0.3	0	0	0	0	0
Schistura desmotes	0.1	0.1	0	0	0	7.8	0	0
Schistura mahnerti	18.7	0	0	2.6	0	0	0	0
Schistura sp. 1	1	0.2	0	0.5	0	29.1	0	0
Schistura sp. 2.	0	0	0	1.5	0	0	0	0.4
Tuberoschistura baenizigeri	1.3	0.2	0	0	0	0	0	0
Cobitidae								
Syncrossus beauforti	1.2	0	0.3	0	0	0	0	0

Table 3. continue.

	Lichia	Kapok	Kratenjeng	Unknown	Kroeng Tako	Satamid	Thi Khrong	Krengkravia
N	5	5	2	1	3	1	1	1
Yasuhikotakia morleti	1.1	0	0.3	0	9.3	0	0	0
Lepidocephalichthys birmanicus	0.4	0.4	0.7	0	0	0	0	0

Table 4. Fishes of the families Balitoridae and Cobitidae in the larger rivers of Thong Pha Phum. Numbers are average numbers of fish·100m^{-2}. N indicates the number of sites sampled.

	Ban Rai	Khayeng		Pracham Mai	
		Tribs	Main	Tribs	Main
N	6	26	13	18	1
Balitoridae					
Acanthocobitis botia	0.2	0	0	1.3	5.2
Acanthocobitis zonalternans	5.7	6.7	3.8	13.3	0.2
Balitora kwangsiensis	1.7	6.6	4.1	0	0
Homaloptera confuzona	0	0	0.1	0	0
Homaloptera smithi	2.9	6.2	6.8	4.7	0.7
Noemacheilus masyae	0.2	0.2	3.8	1.3	0
Schistura desmotes	0	20.6	7.2	1.4	9.9
Schistura mahnerti	0	0.9	0.3	0.2	0.4
Schistura sp. 1.	1.5	12.1	5.1	17.8	0.7
Schistura sp. 3.	0	0	0.2	3.8	0
Tuberoschistura baenzigeri	0	0.2	1.5	<0.1	0
Cobitidae					
Yasuhikotakia eos	0	0	0.1	0	0
Yasuhikotakia morleti	0	0	0.1	0	0
Lepidocephalichthys birmanicus	2	3.4	1	13.6	2.8
Pangio anguillaris	0.1	0.8	0.4	0	0

Table 5. Fishes of the Order Siluriformes from the smaller rivers in Thong Pha Phum. Numbers are average numbers of fish·100m^{-2}. N indicates the number of sites sampled.

	Lichia	Kapok	Kratenjeng	Unknown	Kroeng Tako	Satamid	Thi Khrong	Krengkravia
N	5	5	2	1	3	1	1	1
Bagridae								
Leiocassis siamensis	0	0.2	0	0	1.5	0	0	0
Mystus havmolleri	2.1	1.6	0	0	0	0	0	0.4
Mystus microcanthus	0.1	0	0.2	0	0	0	0	0
Hemibagrus nemurus	0	0.5	1.2	0	0	0	0	0
Siluridae								
Ompok bimaculatus	0.4	0	0	0	0	0	0	0
Pterocryptis cochinchinensis	1.5	0.2	0	0.5	0	0	1.6	0
Amblycipitidae								
Amblyceps maccronatum	0.9	0.1	0	0.5	0	7.1	0	0.4
Sisoridae								
Glyptothorax laoensis	0	0.2	0	0	0	0	0	0
Glyptothorax sp.	0.2	0	0	0	0	4.4	0	0

Table 6. Fishes of the Order Siluriformes from the larger rivers in Thong Pha Phum. Numbers are average numbers of fish·100 m^{-2}. N indicates the number of sites sampled

	Ban Rai	Khayeng		Pracham Mai	
		Tribs	Main	Tribs	Main
N	6	26	13	18	1
Bagridae					
Leiocassis siamensis	5.9	1.1	1.9	0.1	0.1
Mystus havmolleri	3.6	0.6	1.2	4	2.9
Mystus singaringan	0	0	0.1	0	0
Hemibagrus nemurus	1	0.7	0.3	0	0
Siluridae					
Ompok bimaculatus	0.2	0.2	0.2	0	0
Pterocryptis cochinchinensis	0.5	0.1	<0.1	0	0
Sillaginidae					
Sillago maculata	0	0	<0.1	0	0
Amblycipitidae					
Amblyceps maccronatum	2	2	0.4	2.6	0.8
Sisoridae					
Glyptothorax major	0	0.1	0	0	0
Glyptothorax sp.	0	0.2	0	0.2	0.4
Clariidae					
Clarias batrachus	0.1	0	0	0	0

Table 7. Fishes of various families from the smaller rivers in Thong Pha Phum. Numbers are average numbers of fish·100m^{-2}. N indicates the number of sites sampled

	Lichia	Kapok	Kratenjeng	Unknown	Kroeng Tako	Satamid	Thi Khrong	Krengkravia
N	5	5	2	1	3	1	1	1
Notopteridae								
Notopterus notopterus	0	0.1	0	0.5	0.8	0	0	0
Belonidae								
Xenenthodon cancilla	1.3	0.2	0.3	0	0.5	0	0	0
Synbranchidae								
Monopterus albus	0	0	0	0.5	7.2	0	0	0
Mastacembelidae								
Macrognathus sp.	0	0	0	0	0.8	0	0	0
Mastacembelus armatus	2.8	0.7	0.8	0	0.7	0	3.2	1
Ambassidae								
Parabassis siamensis	0	<0.1	0	0	0	0	0	0
Nandidae								
Pristolepis fasciatus	0.3	0	0	0	10.3	0	0	0
Badis badis	0	0	0	0	2.1	0	0	0
Gobiidae	0	0.1	0.8	0	1.5	0	0	0
Belontiidae								
Trichogaster trichopterus	0	0	0	0	0.8	0	0	0
Channidae								
Channa gachua	3.6	0.8	3.3	1.5	19.4	9.2	15.9	0.5
Channa striata	0	0	0	0	0.3	0	0	0
Tetraodontidae								
Tetraodon suvatti	0.1	0.1	0	0	0	0	0	0

Table 8. Fishes of various families from the larger rivers in Thong Pha Phum. Numbers are average numbers of fish·100m^{-2}. N indicates the number of sites sampled.

		Ban Rai	Khayeng		Phracham Mai	
			Tribs	Main	Tribs	Main
	N	6	26	13	18	1
Belonidae						
Xenenthodon cancilla		0.6	1	1	0.3	0.2
Synbranchidae						
Monopterus albus		0	1.5	1.8	0.6	0
Mastacembelidae						
Macrognathus circumcintus		0.4	0	0	0	0
Mastacembelus armatus		1.1	1.6	0.8	0.5	5.5
Ambassidae						
Parambassis siamensis		0.6	0	0	0	0
Nandidae						
Pristolepis fasciatus		0	3	0.3	0	0
Badis badis		1	0	0	0.1	0
Eleotrididae						
Oxyeleotris marmoratus		0	0	2.2	0	0
Gobiidae		2	17.3	1.2	7.3	3.9
Belontiidae						
Trichogaster trichopterus		0.5	0.3	0.8	0	0
Channidae						
Channa gachua		3.8	8.6	2.2	13	8.4
Channa micropeltes		0	0	0.2	0	0
Channa striate		0	0.2	0.2	0	0

Table 9. Limnological characteristics of sampled sites on the smaller rivers in Thon Pha Phum. Substrate, marked with an asterisk is coded as described in the text. The number of sites sampled is identified by N.

	Lichia	Kapok	Unknown	Krengkravia	Thi Khrong	Satamid	Kroeng Tako	Kratenjeng
N	5	5	1	1	1	1	3	2
Elevation, m	190	188	311	290	192	361	168	193
Width, m	3.9	9.9	6.6	8	1.9	3	2.3	6.7
Depth, cm	29	47	24	40	14	22	12	26
Velocity, cm·s^{-1}	39	29	48	67	17	37	17	32
Canopy,%	55	55	80	20	70	70	50	88
Substrate*	6.6	3.3	2	5	3	5	2.3	3.5
Temperature,C^{-1}	22	24.5	23	23.3	23.3	18.4	25.7	23.3
Conductivity, µS·cm^{-1}	192	60	324	186	275	17	411	240
Turbidity, NTU	9.1	2.9	7.6	3.6	1.7	2.3	48	6.9
Color, CU	6.1	1.3	1	0	11	0	137	22
pH	7.9	7.7	8.5	8.5	7.8	7	7.6	8.1
Oxygen, mg·l^{-1}	7.6	8.3	7.8	8.1	6.6	7.9	6.5	7.8
Ammonia, mg^{-1}	0.02	<0.01	0	0	0.01	0	0.17	0
Nitrate, mg·l^{-1}	0.4	2.01	0.2	0.1	0.4	0	12	0.9
Iron, mg·l^{-1}	0.04	0.38	0.1	0.14	0.18	0.03	1.1	0.01
Silica, mg·l^{-1}	19.6	21.6	9.8	12.6	12	20.2	11.3	25
Alkalinity, mg·l^{-1}	144	25	180	99	306	15	576	139

Table 10. Limnological characteristics of the sampled sites on larger rivers in Thon Pha Phum. Substrate, marked with an asterisk is coded as described in the text. N identifies the number of sites sampled.

	Ban Rai	Khayeng		Phacham Mai	
		Tribs	Main	Tribs	Main
N	6	26	13	18	1
Elevation, m	202	245	177	424	388
Width, m	6.3	5.1	7	4.3	16
Depth, cm	23	23	34	24.4	19
Velocity, $cm \cdot s^{-1}$	49	32	30	31	16
Canopy,%	30	48	26	38	10
Substrate*	4.7	5.2	4.1	4.5	7
Temperature,C	26.2	24	25.3	24.6	23.7
Conductivity, $\mu S \cdot cm^{-1}$	92	147	300	77	53
Turbidity, NTU	10.3	11.9	7.2	49	2
Color, CU	34	41.8	14.1	47	18
pH	7.6	7.5	8	7.3	8
Oxygen, $mg \cdot l^{-1}$	7.6	7.5	7.7	7.1	8.2
Ammonia, $mg \cdot l^{-1}$	0.07	0.02	0.01	0.22	0.01
Nitrate, $mg \cdot l^{-1}$	0.16	1.4	1.1	0.45	0.3
Iron, $mg \cdot l^{-1}$	0.7	0.29	0.26	0.53	0.08
Silica, $mg \cdot l^{-1}$	16.4	22.9	14.2	13.7	21.6
Alkalinity, $mg \cdot l^{-1}$	53	99	209	46	26

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